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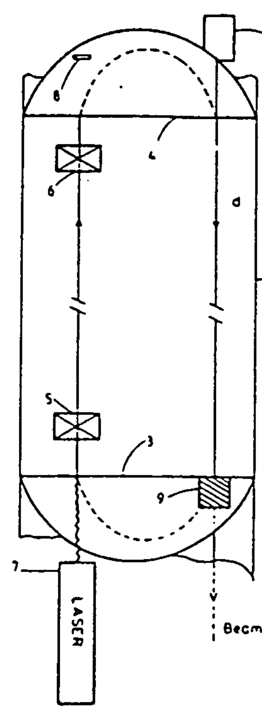
(57) Abstract

A macroscopic baser (boson equivalent of a laser). Bosons such as deuterium particles generated by an ion source (2) are injected into a vacuum tube (1), so as to execute motion on a circulatory path therein. Movement of the bosons in this path may be effected by the use of bending magnets (3) and (4) and focusing of the bosons into a circulating stream is assisted by quatropole magnets (5) and (6). A coherent light beam from a laser is directed into the stream of bosons within the vacuum chamber to effect induced scattering of the bosons within that stream whereby to cause the stream to develop as a coherent beam of bosons which is directed outwardly from the baser by suitable deflection of the circulating stream, such as de-energization of the bending magnets. In other embodiments, the bosons may be reflected in linear fashion.



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helium

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GENERATING A COHERENT BEAM OF BOSONS

This invention relates to the creation of coherent beams of charged bosons for use as an energy source for various purposes. A device effective to so create coherent charged bosons is hereinafter referred to as a "baser".

The mechanism of microscopic basers (boson and analogues of laser) has been described and further studied in the two level decay mode as well as in the independent multiparticle production model in a small volume. The above phenomena are explained by C.S. Lam and S.Y. Lo, Phys. Rev. Lett. 52 1184 (1984). Although the models described in this are valid when the volume is of microscopic size, it is not obvious that the models may be used to achieve a macroscopic baser, that is a baser effective to produce coherent charged bosons on a macroscopic scale.

It is the object of the present invention to provide a system by means of which a macroscopic baser may be produced.

In its broadest form, the invention provides a macroscopic baser comprising means for providing bosons in an evacuated region, and means for producing induced scattering of said bosons to produce a coherent focused boson beam.

More specifically, the invention provides a baser comprising means for providing bosons in an evacuated region, means for reflecting said bosons within said evacuated region, means for focusing the boson beam within said evacuated region, and means for rendering the focused boson beam coherent.

In one preferred form of the invention, the focused boson beam is rendered coherent by means of a laser beam directed along the line of focusing of said boson beam.

Alternatively, the boson beam is rendered coherent by means of a beam of charged particles, such as protons or electrons, directed along the line of focusing of said ion beam.

Where the bosons are charged particles, such as ions, the focusing of the boson beam may be achieved by means of magnetic focusing devices, such as quadrupole magnets. Similarly, the means for reflecting the boson beam may comprise devices such as bending magnets arranged at either end of the evacuated region. Alternatively, electric mirroring may be used to achieve a similar end.

Preferably the bosons are charged. A charged boson is any atomic matter in which B is even and where $B = Z + N + \ell$ (Z: number of protons, N: number of neutrons and ℓ : number of electrons). The charged bosons include nuclear charged bosons in which $\ell = 0$ and Z + N is even, for example deuteron and alpha (Helium nuclei) particles; atomic charged bosons in which $\ell \neq 0$, for example, negatively charged hydrogen atoms and negatively charged helium atoms, or molecular charged bosons such as negatively charged hydrogen molecules.

Generally, it is preferred to use charged bosons, to facilitate control and direction of the bosons within and from the baser by magnetic or electrostatic means. However, using charged bosons has the consequence that the direction or focussing of the stream within the baser, or of the emergent beam, may not be as completely satisfactory as may be desirable for some purposes. This arises because of coulomb forces existing between ions within the stream or within the baser output beam (due to the like charges of these ions) which forces may tend to move the ions away from each other, with components of motion normal to the intended direction of movement thereof.

The possibility of defocusing or misdirection occurring either within the baser itself or within the emergent beam therefrom, may be at least lessened by particular constructions of the baser in accordance with this invention. Thus bosons of a plurality of different charges may be utilized.

The means for producing induced scattering of the ions may thus effective to scatter the bosons of at least one of said charges to produce a coherent focused boson beam.

In one embodiment, bosons of two different polarity charges are moved in paths which over at least respective common portions thereof are substantially coincident. In particular, the bosons of two different charges may move on closed substantially coincident paths such as in loop-like configurations but in opposite directions, means being provided for at least periodically directing the ions of said one charges outwardly from said paths to form said beam. In this instance, although the emergent

beam comprises charged bosons, what is circulated within the baser itself is, in effect, a composite stream formed of two component streams of oppositely charged bosons, whereby the possibility of deviation of the bosons from the desired paths in the baser is reduced. Suitably, the bosons of a first of said charges may comprise deuterons and the ions of a second of said charges may comprise singly negatively charged deuterium ions. Practically, the emergent beam may comprise bosons of a selected one of either of said two charges.

In another form of macroscopic baser constructed in accordance with the invention, bosons of two opposite charges are moved in closed paths which are substantially coincident for only the respective said portions thereof. For example, the paths may be in the form of elongate loops, with respective opposed first and second elongate parallel path portions interconnected at opposite ends of the respective loops by end portions of the loops. These loops may be positioned side by side so that the portions of the corresponding paths which are substantially coincident comprise respective ones of the two elongate path portions of each loop. In this instance, oppositely charged bosons may be moved, in circulatory fashion around each loop, in oppositely directed directional senses whereby, at the substantially coincident portions of the paths, the bosons moving on each path move side by side or in intermingled fashion in the same direction. In this instance, the bosons of the two different charges may be injected into the paths of movement for each at locations towards respective adjacent one ends of the elongate loops for injection

into the substantially coincident path portions at one end thereof and the beam which is directed from the baser is arranged to emerge at a location between the two elongate loops at the opposite ends of the substantially coincident path portions. In this case the composite stream of bosons which passes along the common portions of the two loops will comprise a mixture of bosons of the two different charges and the resultant exit beam will also comprise a mixture of these. In this instance, the means for producing induced scattering may comprise means for injecting a coherent light beam, photons or other particles, into the streams at appropriate locations around the said paths. As before, the bosons of a first of said charges may comprise deuterons and the bosons of a second of said charges may comprise single negatively charged deuterium ions.

In another embodiment, a number such as four streams of bosons are moved on respective closed paths within the baser, these being arranged in an array which extends in two directions in the plane transverse to the intended direction of emergence of the boson beam. In one embodiment four such streams are provided, each moved in a respective elongated closed paths with alternate ones around the array having bosons of respective opposite polarities moved therearound. Adjacent paths may have common portions extending in a lengthwise direction of the baser so that over these adjacent portions bosons of the two different charges are moved therethrough. In such a case, there may be four such common path portions preferably arranged in a rectangular array when viewed in transverse section. At two opposed ones of these

within the array, bosons of one charge polarity and bosons of the opposite charge polarity are respectively injected at locations towards adjacent one ends of the paths. At adjacent opposite ends of the paths and at a corresponding one end of the baser two beams of the charged bosons are taken from the baser. At the other two opposed path portions, at said one ends of the paths, coherent light beams or other particles that may cause induced scattering are injected to induce coherence in the exiting beams.

Several preferred embodiments of the invention will now be described with reference to the accompanying drawings in which:

Figures 1 to 8 are schematic representations of respective different basers, figures 1 to 7 being schematic side views of the different basers, and figure 8 being a schematic transverse section of the baser of figure 7.

Before describing the presently preferred embodiments of systems according to the invention, it is appropriate to discuss the theory behind the mechanism achieved by each preferred system. In the following discussion, the use of a laser to induce the ion beam to become coherent is described although it should be appreciated that any one of the alternative mechanisms defined generally above may be used to achieve a similar effect.

Let us consider a beam of bosons, which are called α, travelling in a closed path in a tube of dimension 1m x 1cm^2. Due to the discrete normalization of the wave functions, quantization requirements allow 10^{16} discrete momentum states in a momentum spread of 1eV/c in all direction. On a

random base there will be practically no two bosons occupying the same momentum state for an ordinary beam of particles of size $n \sim 10^{13}$ with a momentum spread a few KeV/c. It is possible, however, to scatter the α - beam gently with another set of particles, which are called γ, such that α - bosons in the beam will group together into the same momentum state after many scatterings, due to the boson nature of the α's.

Let us assume that phenomenological Hamiltonian density for elastic scattering between bosons α and particles γ to be given by

$$H(x) = g\,\phi(x)\,\phi(x)\,A(x)\,A(x) \qquad (1)$$

where $\phi(x)$ and $A(x)$ are the quantum field for α and γ respectively, and g is the phenomenological dimensionless coupling constant. Spin is an unnecessary complication and will be neglected. By the use of N^{th} order perturbation theory where the transition rate is given by

$$W = 2\pi\,\Sigma\,\left|\langle f\,|\,H\left(\frac{1}{\Delta E}H\right)^{n-1}|i\rangle\right|^2 \delta\,(E_f - E_0) \qquad (2)$$

it is possible to derive formulae for various kinds of elastic scatterings.

The simplest kind of elastic scattering is between two particles

$\alpha(p) + \gamma(k) \rightarrow \alpha(p') + \gamma(k')$ with momenta as labelled. Its probability P_1, transition rate W_1 and cross section σ_1 are given by:

$$P_1 = \frac{g^2 T}{16\pi V}\,\frac{|\vec{k}'|}{p_0 k_0 E_0}$$

$$W_1 = \frac{g^2}{16\pi V}\,\frac{|k'|}{p_0 k_0 E_T} = v_{rel}\,\frac{\sigma_1}{V} \qquad (3)$$

$$\sigma_1 = \frac{1}{v_{rel}}\,\frac{g^2}{16\pi}\,\frac{|\vec{k}'|}{p_0 k_0 E_0}$$

where V is the normalization volume, T the period of particle travelling around a closed tube, v_{rel} is the relative velocity between α and γ , $E_o = p_o + k_o$ is the total energy, and $\vec{k}'$, p_o, k_o are all evaluated at the centre of mass frame.

For the elastic scattering of two particles where there is in the background a group of α bosons in momentum state (p'), it will be induced to scatter into the same final state as the n α :

$$\alpha(p) + \gamma(k) + n\alpha(p') \rightarrow (n+1)\alpha(p') + \gamma(k') \qquad (4)$$

The transition rate W_n is given by the application of (2) to be

$$W_n = (n + 1)\, \eta\, w_1 \qquad (5)$$

where

$$\eta = \frac{\pi E_0}{A\, p_0 k_0 |\vec{k}| v} \qquad (6)$$

This formula has a simple physical interpretation. The (n + 1) factor comes from the annhilation operator of the α -boson on the final state $\langle n | a_\alpha = \langle n+1 | \sqrt{n+1}$, and the η factor comes from the fact that the p'-momentum state is only one of many available momentum states available:

$n = 1/$(Total available momentum states). The number of available states is

$$\frac{V \times 4\pi\, p^2 \Delta p'}{(2\pi)^3} = \frac{Vp'^2}{2\pi^2}\,\frac{\Delta p'}{\Delta p_0}\,\Delta p'_0 \sim \frac{1}{n} \qquad (7)$$

utilizing the fact that V=A (cross section of the beam) x 1 (length of the tube), 1=v (= velocity of the α -beam in the tube) x T (period of the circulating α -beam), and $\Delta E \sim 2\pi/T$ from the uncertainty principle.

The rate equation for the growth of the n coherent α boson in state p' created by scattering with a beam of $n_\gamma \gamma$ particles is:

$$\frac{dn}{dt} = (-nw_l + w_n n_i)n_\gamma \qquad (8)$$

where n_i is the number of α particles in the beam which it is kinematically possible to scatter into a definite final state p' by particle γ with initial momentum k. The first term nw_l is the loss rate at which n coherent α particles are scattered by $n_\gamma \gamma$ particles to become different momentum states in the final states. The second term indicates the increase of coherent α-bosons due to the scattering of γ -particles with the α -beam. The combination of (5) and (8) produces the critical condition for the occurrence of macroscopic baser phenomena to be

$$n\,n_i > 1 \qquad (9)$$

The growth constant λ that governs the growth of the baser beam is defined by

$$\frac{dn}{dt} = n\lambda$$

$$n = n_o e^{\lambda t} \tag{10}$$

In the case of no other loss, λ is given by

$$\lambda = n_\gamma w_1 \,(n_i n - 1) = n_\gamma w_1 n_i n. \tag{11}$$

To appreciate the reality of equations (9) and (11) it is helpful to discuss a special case: the scattering of α particles (= nucleus of the He-atom) by photons (γ) from a laser.

Consider an α -beam which has a kinetic energy K and momentum p with a momentum spread of Δ gaussian shape centering around some central momentum p_o:

$$S(p) = \left(\frac{1}{\Delta}\right)^{3/2} \exp\left(-(p-p_o)^2 / \Delta^2\right) \tag{12}$$

Kinematically only a small fraction ($\Delta N/N$) of the α -beam can be scattered by photons with energy k_o to a fixed final momentum p' given by

$$\left(\frac{\Delta N}{N}\right) \simeq 8\pi^{-3/2} \left(\frac{k_o}{\Delta}\right)^3 \frac{\Delta k_o}{k_o} \tag{13}$$

and then

$$n_{\gamma} = N\left(\frac{\Delta N}{N}\right)$$

where N is the total number of α -particles in the beam. The critical condition becomes:

$$N > \left(\frac{N}{\Delta N}\right)\frac{1}{\eta} \tag{14}$$

Table 1 contains values of η and N for the case of beam with kinetic energies K=1 keV, 10keV, 100 KeV with beam cross section of A=1 cm^2 and $1mm^2$. The spread of momentum Δ /p is taken to be 0.1%, and the energy of the photons is k_o = 1eV. The ranges of various parameters as shown in Table 1 are quite within the limits of present technology. To calculate the growth constant one requires the value of the cross section of low energy photon- α scattering which is $\sigma = 8\ \pi\ \alpha^2/e\ m\alpha\ ^2 = 1.3 \times 10^{-32} cm^2$. Some typical values are given in the following table:

TABLE 1

K	A	$\frac{\Delta N}{N}$	n_γ	N	λ(1/sec)
1 keV	1 cm2	4.4 x 10-15	1024	1024	284
1 keV	1 mm2	4.4 x 10-14	1021	1020	284

Thus, a smaller beam size has enormous advantage over the larger beam since $\lambda \propto 1/A^2$.

The use of a laser to induce the α-beam to become coherent has a useful effect because the laser beam itself consists of coherent photons. Let n_γ and n be the number of coherent photons and α-particles with momentum k and p with $n_\gamma > n$. The transition rate for their elastic scattering:

$$n_\gamma(k) + n(p) \rightarrow (n_\gamma - n)\ (k) + k_1' + \ldots k_n' + p_1' + \ldots p_n'$$

where k'_i, p'_i are momenta of the photons and α in the final states which are not necessarily coherent, is

$$W_0 = \frac{n_\gamma!(n!)^2}{(n_\gamma - n)!} \prod_i^{n-1} [P_1(1+in)] w_1 \tag{15}$$

The result comes strictly from the application of the n^{th} order perturbation theory of eq.(2), but it does have a simple explanation. Whenever n coherent bosons participate together, it is easy to have n! in the rate because of the property of the annihilation operator of bosons such as:

$$a\ a \ldots a\,|n(k)\rangle = \sqrt{n!}\ |0\rangle \tag{16}$$

The initial n_γ photons in the scattering gives a $n_\gamma(n_\gamma - 1)\ldots(n_\gamma - n+1)$ because only $(n_\gamma - n)$ initial photons participate in the interaction. The $(n!)^2$ in the numerator comes from n α-particles in the

initial state and final state. The last multiplicative factor comes from a summation of all final states which may be coherent or may not be coherent. Even when the $n(\gamma)$ and $n(\alpha)$ in the final state are coherent with the same momenta $k'_1 = k'$, $p'_i = p'$, it is extremely unlikely they are the same as the initial momenta. Hence the above kind of transition represents a loss of the coherent beam. Because the transition probability $p_1 = (V_{rel}/V)\ (\sigma/A) \sim 10^{-29}$ is extremely small, it is insignificant in the beginning. It becomes significant only when n grows to the order of 10^7. However, when the number n of the coherent beam grows, there is an additional favourable fact tending to increase the coherent beam. Quite unlike the laser, where there is only momentum in its beam, the coherent beam obtained from induced elastic scattering can grow around different momentum states. Assume there are $n_1(p_1)$ α with momentum p_1 and $n_2(p_2)$ α with momentum p_2, there are induced elastic scatterings of the following type:

$$n_\gamma(k) + n_1(p_1) + n_2(p_2) \to (n_\gamma - n_1)(k) + (n_1+n_2)(p_2) + k'_1 + \ldots . k'_{n_1} \qquad (17)$$

The original n_2 α -particles and $(n_\gamma - n_1)(k)$ photons do not change momentum. They behave like spectators except that the presence of $n_2(p_2)$ α -particles acts to induce the $n_1(p_1)$ α to be scattered into momentum state p_2. The transition rate is given by

$$W_c = \frac{n_\gamma}{(n_\gamma - n_1)!} \ \frac{(n_1+n_2)!}{n_2!} \ (n_1!)^2 P_1^{\,n_1-1} \ n^{n_1} w_1 \qquad (18)$$

The ratio of W_c/W_o is:

$$r = \frac{W_c}{W_o} = \frac{(n_1 + n_2)!}{n_2!}\, n \qquad (19)$$

which will become bigger than 1 when $n_1 \sim n_2 >> 10$. Hence induced elastic scattering favours the growth of a coherent beam en masse whenever this is kinematically allowed. This phenomenon may be called block switching (14).

If equation (18) is rewritten in terms of transition probability for process (17) it takes the following form:

$$P_c = \frac{n_\gamma!}{(n_\gamma - n_1)!}\, \frac{(n_1 + n_2)!}{n_2!}\, (n_1!)^2\, (P_1 n)^{n_1} \qquad (20)$$

The transition probability grows rapidly with n_1 but because of unitarity it cannot exceed 1. The limit is reached when $n \sim 6 \times 10^8$ for the value of $P_1 \sim 10^{-29}$, $n \sim 10^{-5}$. It is clear that when the limit is reached, the N^{th} order perturbation theory becomes insufficient. It is then necessary to treat the scattering processes to all order.

The availability of macroscopic basers has many practical consequences. By comparison with the laser one immediately observes that the baser can be made up of charged bosons which can then be accelerated to much higher energies, MeV, GeV, TeV etc. by normal mechanisms. Unlike photons, charged bosons are normally strongly interacting particles. Just as

lasers help to study nonlinear effects and rare effects in atomic and molecular levels, basers may be used to create and to study the nonlinear effects, exotic states, exotic scattering and production processes etc., in nuclear and hadronic levels.

Referring now to Figures 1 to 4 of the drawings, several embodiments of the invention are now schematically described.

Referring firstly to Figure 1 of the drawings, the system will be seen to comprise a vacuum tube 1 (alternatively the apparatus may be arranged in a vacuum chamber), an ion source 2 for creating a beam of deuterons d within the vacuum tube, a pair of bending magnets 3 and 4 which cause the deuteron beam d to be reflected within the vacuum chamber 1, a pair of quadrupole magnets 5 and 6 which cause focusing of the deuteron beam d and a laser 7 adapted to project a laser beam into the vacuum tube 1 through a transparent hole in the vacuum tube 1 in alignment with the deuteron beam d focused by the quadrupole magnets 5 and 6, the laser 7 including a reflecting mirror or a prism 8 positioned to reflect the laser beam in a suitable manner. As explained in the theoretical description above, the laser beam has the effect of rendering the deuteron beam d coherent. A kick-off mechanism 9 is provided to allow the coherent deuteron beam to be released from the device and in the present embodiment this mechanism 9 may take the form of means which neutralises the magnetic field of the bending magnet in the position shown. Alternatively, an electric kick-off mechanism may be provided.

Where a monochromatic deuteron beam is required, the quadrupole magnets may be turned off. Operation

of the above described laser induced deuteron-Baser (d-baser) may be in either a continuous mode or may be in a pulsed mode. One use for the d-baser lies in thermonuclear fusion.

In the above embodiment, the ion source 2 may comprise a 1keV to 100keV deuteron alpha particle (or other nuclear ion) source such as that manufactured by Ortec Inc. of Oakridge Tennesse U.S.A.

The bending magnets 3 and 4 should be suitable for turning particles having momentum in the MeV/C range through 180°. Similarly, the quadrupole magnets 5 and 6 should be capable of focusing particles having the same momentum. Suitable magnets are manufactured by Nuclear Accessories Co. Ltd. of Auckland, New Zealand.

The laser 7 may be a 20 watt or more carbon dioxide laser made by California Laser Corporation of San Marco California, U.S.A.

The kick-off mechanism 9 may be a bending magnet of the type referred to above.

Referring now to the embodiment of Figure 2 of the drawings, the device is similar in construction to the embodiment of Figure 1 and accordingly similar reference numerals are used to indicate similar components. In this embodiment a further ion source 12 is positioned to emit a stream of protons p which is focused by means of quadrupole magnets 15 and 16 positioned so that the proton beam p is brought into alignment with the deuteron beam d. The mechanism is otherwise similar to that described in relation to Figure 1 of the drawings. However, since the protons induce a stronger interaction than the photons emitted by the laser in the previous embodiment, the reaction

rate may be much higher than in the previous embodiment. A gain of 10^5 in the reaction rate may be expected.

Referring now to Figure 3 of the drawings this embodiment is again similar to the embodiment of Figure 1 of the drawings with the exception that a further ion source 22 is provided to emit an electron beam e which is focused by quadrupole magnets 25 and 26 and reflected into alignment with the deuteron beam d by means of bending magnets 23 and 24. In this arrangement the use of an electron beam to render the deuteron beam coherent has the advantage that the negative charge of the beam helps to reduce electrostatic energy problems. Since the mass of the electrons in the electron beam e is considerably smaller than the mass of the deuterons, it is necessary to have a much weaker bending magnet to correctly position the electron beam.

Referring now to Figure 4 of the drawings, an electric mirroring mechanism is used to achieve the same end as the bending magnets 3 and 4 in the previous embodiments. In this embodiment, the deuteron beam d is aligned with the axis of the vacuum tube 30 by means of a bending magnet 10. A pair of electrically conductive plates 31 and 32 are provided at either end of the vacuum tube 30 and are held at a voltage $V_t = 2V_i$ (ion source energy = qV_i). A laser 7 projects a photon beam through a transparent spot in the centre of the plate 32 and a movable mirror 33 is located to cover an aperture 34 in the plate 31 at the other end of the tube 30. Once a coherent beam of deuterons d has been produced, the movable mirror is moved to allow the coherent beam to be emitted. A

quadrupole magnet (not shown) may be arranged outside the vacuum tube 30 if focusing of the ion beam is required. This arrangement is preferred for the production of a low energy coherent deuteron beam.

Some of the uses for the above described embodiments include:

1. Thermonuclear fusion in which the coherent deuteron beam is directed at a deuterium or trinium pellet after acceleration to the required level by conventional methods. This method is similar to the implosion method using lasers except that the substitution of d-baser renders the device many times more powerful.

2. As an ion source for accelerators. The advantage of the baser in this case is it has discrete momentum and simplification of the high energy accelerator because of the coherence of the beam.

3. As an ion source for a microprobe or a nuclei analogy of a microscope.

4. The production of nuclear holographs, atomic holograph or molecular holographs. The principle is similar to that of the use of lasers to produce holographs.

Coherent neutral particle beams may be obtained by placing a suitable material in front of the coherent charged boson beam. For example,

$$H^{--} \rightarrow H + e^-e^-$$

atom

$$H_2^{--} \rightarrow H_2 + e^- + e^-$$

Figure 5 shows a vaccuum chamber 1 of elongate loop like form comprising a pair of parallel tubes 56, 58 interconnected, at one pair of adjacent ends of the tubes, by a curved tubular portion 62 and, at the other pair of adjacent ends, by a curved tubular portion 60. An ion source 2, in use generating deuterons, is positioned at one end of the baser, more particularly at the end of tube 58 adjacent portion 62, and is arranged to inject a stream of deuterons into the tube 58, at that tube end, for travel into the chamber 1, so as to traverse a loop-like path 70 extending along tube 58, thence around end portion 60, through tube 56, around end portion 62 and thence to return to tube 58 whereby deuterons in use continuously circulate around path 70.

The guiding of the deuterons around the end portions 60, 62 is effected by use of bending magnets 3 and 4, and focusing means in the form of two quadrupole magnets 5 and 6 are provided in the tube 56 for the purpose of maintaining the stream of deuterons in a focused flow path.

A second ion source 52 is provided effective to generate deuterium ions which are singly negatively charged. This ion source is positioned at the same end of the baser as the source 2 but is positioned to inject the aforementioned deuterium ions into the tube 56 at the end adjacent end portion 62 whereby the ions traverse the chamber 1 in the closed loop like path 72 shown, which path extends along tube 56, around end portion 60 thence along tube 58, to return via end portion 62 to tube 56. This path 72 is largely coincident with path 70, but it will be observed that the deuterium ions traverse around the chamber 1 in a

clockwise direction whereas the deuterons traverse in an anticlockwise direction.

A laser 7 producing coherent light is positioned at the end of the baser adjacent end portion 60 of chamber 1 and is arranged to inject coherent light into tube 56 at the end thereof adjacent end portion 60 to travel down the tube 72. A mirror or prism 8 is positioned at the opposite end of tube 56 to reflect such coherent light back towards the end of tube 56 adjacent end portion 60.

A kick-off device 9 is provided at the end of tube 58 adjacent end portion 60 of chamber 1. This is effective, such as by de-energising bending magnet 3, to cause deuterons travelling on path 70 along tube 58 to be exited from the vaccuum chamber 1 at the end of the tube 58 adjacent end portion 60 rather than to be directed around the end portion 60. The kick off device may, for example, comprise means for momentarily or otherwise de-energising the bending magnet 3. Thus, a beam 74 of deuteons is caused to exit the baser via the kick off device 9.

The light from the laser 7 causes induced scattering in the deuterons and the deuterium ions traversing paths 70 and 72 thereby tending to cause the streams to be brought into a coherent state, thus the exiting deuteron beam 74 comprises a coherent beam of deuterons.

Although in the described arrangement the beam 74 is electrically charged (being positively charged) on account of the positive charge carried by the deuterons forming the beam, the net charge of the co-extensive streams of deuterons and deuterium ions

flowing on these substantially coincident paths 70, 72 is zero, the positive charge of the deuterons being cancelled by the negative charge of the deuterium ions so that the composite stream comprising both particles as moved around the paths 70 and 72 is electrically neutral. For this reason, there is considerably lessened chance that the deuterons will be subjected to components of motion normal to the paths 70, 72 under influence of coulomb forces. Thus tendency for the streams to defocus within the chamber 1 is reduced and coherence is enhanced.

Whilst in Figure 5 deuterons are taken by the kick off apparatus 9 to form the beam 74 which exits the baser, it is possible to arrange for take off of the deuterium ions instead, so as to produce a coherent beam of deuterium ions. This may be simply effected by interchanging the positions of the laser 7 and kick off mechanism 9.

Of course, further focusing devices such as the quadrupole magnets 5 and 6 may be positioned within the chamber 1 to facilitate maintenance of focused streams of the deuterons and deuterium ions; particularly these may be provided in tube 58 in a similar manner to the arrangement of quadrupole magnets 5 and 6 in tube 56.

In figure 6 the vaccuum chamber 1 comprises three parallel side by side tubes 80, 82, 84. Tubes 80, 82 are interconnected at one pair of adjacent ends by an end portion 85 of chamber 1 and the other pair of adjacent ends by an end portion 86 of chamber 1. Similarly tubes 82, 84 are interconnected at one pair of respective adjacent ends by an end portion 88 of

chamber 1 whilst the other adjacent ends of these tubes are interconnected by an end portion 90 of the chamber 1. In this arrangement, deuterium ions, singly negatively charged, and deuterons are introduced in side by side streams into tube 82 at one end of the chamber 1, particularly at the end of the chamber adjacent end portions 85 and 88 and are caused to be guided around respective paths 98 and 100 into chamber 1 by the use of magnets and quadrupole magnets in an analogous fashion to that described in figure 1. In particular, the path 98 on which the deuterium ions are moved is of elongate closed loop like form extending down tube 82 from the point of introduction of these ions into the tube 82 thence through end portion 86, along tube 80, around end portion 85 to be returned to tube 82. On the other hand, the path 100 on which the deuterons move is likewise of elongate loop like form extending down the tube 82, around the end portion 90 of the chamber 1 through tube 84, thence around end portion 88 of chamber 1 to be reintroduced into tube 82.

For the purpose of generating induced scattering into the deuterium ions and deuterons moving on the paths 98 100, photons in coherent light beams 87, 89 are directed into the tubes 80 and 84 at locations shown in Figure 6, namely at the ends of the respective tubes 80, 84 adjacent the portions 85 and 88 of the chamber 1. These light beams 87,89 may be generated by lasers and reflected by mirror or prism as previously described. Deuterons and deuterium ions moving down the tube 82 are directed in a beam outwardly of the baser from the end of tube 82 adjacently portions of 86, 90 of the chamber 1. This

may, again, be effected by the use of a kick off mechanism analogous to the previously described kick off mechanism 9. The emergent beam 102 in this instance comprises a mixture of deuterium ions and deuterons.

The arrangement of Figure 6 has the advantage that the beam which is produced by the baser is a coherent beam of neutral electrical characteristics by virtue of the intermingled oppositely charged deuterium ions and deuterons. Furthermore, over substantial parts of the paths of movement of the deuterium ions and deuterons within the chamber 1, namely over the portions which traverse tube 82, the composite stream of deuterons and deuterium ions is of net neutral charge.

In the arrangement of Figures 7 and 8, vaccuum chamber 1 comprises four parallel lengthwise extending tubes 120, 122, 124, 126 arranged, when viewed in transverse section of the chamber 1, in the rectangular array shown particularly in Figure 8. In Figure 7, the chambers are shown in side by side relationship for clarity. At first and second pairs of adjacent ends the tubes 126, 120 are interconnected by respective end portions 130, 132. At first and second pairs of adjacent ends the tubes 120, 122 are interconnected by respective end portions 134, 136. At first and second pairs of adjacent ends the tubes 122, 124 are interconnected by respective end portions 138, 140. At first and second pairs of adjacent ends the tubes 124, 126 are interconnected by respective end portions 142, 144 of the chamber 1. Thus, the tubes 120, 126 with end portions 130, 132 define a first elongate loop like chamber portion, tubes 120,

122 together with the end portions 134, 136 define a second elongate loop like chamber portion, tubes 122 and 124 and end portions 138, 140 define a third elongate loop like chamber portion and the tubes 124 and 126 and end portions 142 and 144 define a fourth elongate loop like chamber portion. The fourth and first chamber portions are common over the length of tube 126, the first and second chamber portions being common over the length of tube 120, the second and third chamber portions being common over the length of tube 122 and the third and fourth chamber portions being common over the length of tube 124.

At one end of the baser shown in Figure 3, singly negatively charged deuterium ions and deuterons are injected into the chamber 1. On the one hand, deuterium ions and deuterons are directed into the tube 120 at the end thereof adjacent end portions 130, 134 of the chamber. On the other hand, further deuterium ions and deuterons are directed into tube 124 at the end thereof adjacent end portions 138, 142 of the chamber 1. The deuterium ions injected into tube 120 travel down the tube 120 around the end portion 132, through tube 126 and thence through end portion 130 of chamber 1 to move through the aforementioned first chamber portion in the closed elongate loop like path 145 shown. Similarly, the deuterons passed into tube 120 move down the tube 120, around end portion 136, along tube 122, through end portion 134, back into tube 120 in the closed elongate loop like path 146 shown, within the second of the aforementioned chamber portions. The deuterium ions injected into tube 124 move along tube 124 round end portion 140, through tube 122, around end portion 138

and thence to be directed back to tube 124 whereby to move on the closed elongate loop like path 148 shown, within the third of the aforementioned chamber portions. The deuterons injected into tube 124 move along tube 124, around end portion 144 of chamber 1, along tube 126, around end portion 142 to be redirected into tube 124 so as to move on the closed elongate loop like path 150 shown, within the aforementioned fourth portion of the chamber 1. Direction of the deuterium ions and deuterons on these paths and any necessary focusing is achieved by use of bending magnets and quadrupole magnets as aforementioned in relationship to the embodiments of Figures 1 and 2.

Coherent light, designated by reference numerals 160, 162 is directed into tubes 126 and 122 so as to cause induced scattering of deuterons moving on the path 150 and of deuterium ions moving on path 148, and also of the deuterons moving on path 146 and of deuterium ions moving on path 145. If desired reflectors like the mirror or prism 8 previously described may be positioned at the end of tubes 126 and 122 remote from the points of injection of light thereto to reflect the light back towards the injection point. As before, the coherent light may be generated by lasers.

By use of suitable deflecting kick off devices such as the aforedescribed device 9, coherent beams each comprised of intermingled deuterium ions and deuterons exit from the apparatus at ends of tubes 120 and 124, being ends of these tubes opposite the ends thereof at which deuterons and deuterium ions are introduced.

The arrangement of Figures 7 and 8 has the advantage that coherent beams of ions are produced which beams each have net neutral charge by virtue of the mixture of ions of different polarities, whilst at the same time, the streams of deuterons and deuteriom ions moving on paths 150, 148, 146 and 145 are over almost the entirity of the lengths thereof intermingled to likewise have a net neutral charge. Thus, the tendency of the exiting beams to defocus is minimised whilst, at the same time, tendency of the streams of ions moving within the basar itself to likewise defocus is also minimised.

Of course, the arrangement of Figures 7 and 8 could be extended to include a number of paths greater than the four paths shown, 145, 146, 148 and 150. For example, an array which, viewed in transverse section, included eight, twelve, sixteen or more such paths may be constructed.

While, in the described arrangements the vaccuum chamber 1 is formed of tubes interconnected by end portions to define loop-like chamber portions, it is not essential that this be of the case. In particular, the vaccuum chamber 1 may simply comprise, in each instance, a chamber which surrounds, as a group, all of the paths of movement of particles within the baser.

Also, whilst in the described embodiments of figures 5 to 8, the baser has been described as operating with ion streams formed of deuterium ions and deuterons, other charged particles as previously described may be employed.

The invention can be applied to form a fusion reactor operating to release energy by the process:

$$d + d = He + n$$

that is to say by the process involving fusion of two deuterium nuclei (deuterons) to form a Helium nuclei and a neutron.

One of the two deuterons may be provided as a compound of deuterium, such as deuterium oxide (D_2O), such as in pellet form and the other may be provided by the baser of this invention. By this process, then, the deuterium oxide is subjected to one or more beams of coherent deuterons provided by one or more basers of the invention.

The beams may thus be applied from various different directions as in a three dimensional array directed against pellets of deuteron containing material, these pellets being supplied sequentially, such as continuously, to a reaction region.

In comparison with nuclear fusion processes involving direction of coherent photon beams against a deuteron - containing material in the well-known implosion method for producing nuclear fusion energy, the coherent deuteron beam from a baser of this invention has two distinct advantages. Firstly each deuteron particle in the coherent deuteron beam has energies in the range of keV to 10^2 keV, which is 10^3 to 10^5 times that of the photons produced in a laser. Secondly the coherent deuteron beam itself interacts directly with the deuteron pellet, and hence can produce nuclear fusion more effectively and instantaneously.

Hence, the size of such a nuclear fusion reactor can be smaller, possibly allowing the device to be made portable.

The nuclear fusion process of the invention may be practiced wherein coherent nuclei other than deuterium nuclei are fused. The process may employ mixtures of deuterium and tritium nuclei.

The described arrangements have been advanced merely by way of explanation and many modifications may be made thereto without departing from the spirit and scope of the invention as defined in the appended claims.

CLAIMS:

1. A macroscopic baser comprising means for providing bosons in an evacuated region, and means for producing induced scattering of said bosons to produce a coherent focused boson beam.

2. A macroscopic baser as claimed in claim 1 further comprising reflecting means for reflecting said bosons within said evacuated region.

3. A macroscopic baser as claimed in claim 2 wherein said reflecting means comprises bending magnets arranged at either end of the evacuated region.

4. A macroscopic baser as claimed in any one claim 2 or claim 3 wherein said reflecting means comprises electric mirrors.

5. A macroscopic baser as claimed in any one of claims 2 to 4 wherein said reflecting means is in use effective to cause said bosons to execute a back and forth movement along a substantially common path within the evacuated region.

6. A macroscopic baser as claimed in any one of claims 2 to 4 wherein the reflecting means is in use effective to cause the bosons to execute a circulatory movement within the evacuated region.

7. A macroscopic baser as claimed in any preceding claim including focusing means for focusing the bosons into a stream within said evacuated region.

8. A macroscopic baser as claimed in claim 7 wherein said focusing means comprises magnetic focusing devices.

9. A macroscopic baser as claimed in any preceding claim wherein said means for producing induced scattering comprises a laser beam directed into said bosons.

10. A macroscopic baser as claimed in any one of claims 1 to 8 wherein said means for producing induced scattering comprises a beam of charged particles directed into said bosons.

11. A macroscopic baser as claimed in claim 10 wherein said beam of charged particles comprises a beam of protons.

12. A macroscopic baser as claimed in claim 10 wherein said beam of charged particles comprises a beam of electrons.

13. A macroscopic baser as claimed in any preceding claim wherein said means for providing bosons in an evacuated region is effective in use to provide therein bosons of a plurality of different charges.

14. A macroscopic baser as claimed in claim 13 wherein said means for producing induced scattering of the bosons is effective in use to scatter the bosons of at least one of said charges to produce the coherent focused boson beam of those bosons.

15. A macroscopic baser as claimed in claim 14 arranged and constructed whereby in use bosons of two opposite charges are moved in paths which are over at least respective common portions thereof substantially coincident.

16. A macroscopic baser as claimed in claim 15 arranged and constructed whereby in use said bosons of two opposite charges are moved on closed substantially coincident paths, but in opposite directions, means being provided for at least periodically directing the bosons of one of said charges outwardly from the corresponding said path to form said boson beam.

17. A macroscopic baser as claimed in claim 14 arranged and constructed whereby in use said paths are closed and the common portions thereof comprise less than the whole of each respective path whereby in use to form over the common portions a composite stream of bosons of said two opposite charges which stream is in use caused to exit the baser to form said boson beam.

18. A macroscopic baser as claimed in claim 17 wherein said paths are in the form of elongate loops each defining opposed first and second elongate parallel path portions which are, for each loop, interconnected

at opposite ends of the respective loop by end portions of the loop.

19. A macroscopic baser as claimed in claim 18 wherein said loops are positioned side by side so that the common portions of these comprise respective ones of the two elongate path portions of each loop.

20. A macroscopic baser as claimed in claim 19 arranged and constructed whereby in use the bosons are moved in circulatory fashion around each loop in opposite rotational senses whereby, at the common portions of the paths, the bosons moving on each path move side by side or in intermingled fashion in the same direction.

21. A macroscopic baser as claimed in claim 19 or claim 20 arranged and constructed whereby in use said bosons of two opposite charges are injected into the paths of movement for each adjacent the entry point to said common portions thereof.

22. A macroscopic baser as claimed in claim 21 wherein the means for producing induced scattering comprises means for injecting photons in a coherent light beam, or other particles, into the bosons moving in each path, at a respective location around each said path.

23. A macroscopic baser as claimed in claim 15 arranged and constructed wherein in use the bosons are moved in at least four streams on respective closed paths arranged in an array which extends in two

directions in the plane transverse in the intended direction of emergence of the boson beam.

24. A macroscopic baser as claimed in claim 23 wherein adjacent ones of the closed paths within the array in use have bosons of respective opposite polarities moved therearound.

25. A macroscopic baser as claimed in claim 24 wherein each said path has two common portions, respective ones of which are substantially coincident with respective ones of two side by side said paths in the array, said common portions extending in a lengthwise direction of the baser, bosons of the two different charges being in use advanced in the same direction along each said common path portion.

26. A macroscopic baser as claimed in claim 25 wherein the common path portions are arranged in a rectangular array when viewed in transverse section.

27. A macroscopic baser as claimed in claim 26, wherein at two transversely opposed ones of said common path portions within the array, bosons of one charge polarity and bosons of the opposite charge polarity are injected at locations towards adjacent one ends of the paths whereby bosons of each of said two opposite charges then form composite streams of substantially net neutral electric charge within these two common path portions.

28. A macroscopic baser as claimed in claim 27 arranged and constructed whereby in use at adjacent

ends of the paths, opposite said one ends thereof, two beams of the bosons are taken from the baser, whereby these beams each comprise bosons of each of said two different polarities to render said beams of substantially neutral net electric charge.

29. A macroscopic baser as claimed in claim 28 constructed and arranged whereby, in use, at two other opposed ones of said common path portions, coherent light beams or other particles are injected to produce induced scattering whereby to render coherent the bosons travelling in those path portions.

30. A macroscopic baser as claimed in any preceding claim wherein the bosons comprise ions.

31. A macroscopic baser as claimed in any one of claims 15 to 29 wherein said bosons of a first of said charges comprise deuterons and the bosons of a second of said charges comprise singly negatively charged deuterium ions.

32. A method of forming a coherent beam of bosons comprising providing said bosons in an evacuated region and producing induced scattering of said bosons.

33. A method as claimed in claim 32 wherein said bosons are reflected within said evacuated region.

34. A method as claimed in claim 33 wherein said reflecting is effected back and forth along a substantially common path within the evacuated region.

35. A method as claimed in claim 33 wherein said reflecting is effected whereby to cause the bosons to execute a circulatory movement with the evacuated region.

36. A method as claimed in any one of claims 32 to 35 further comprising focusing said beam within said evacuated region.

37. A method as claimed in any one of claims 32 to 36 wherein said scattering is induced by directing into said bosons a beam of coherent light.

38. A method as claimed in any one of claims 32 to 36 wherein said induced scattering is effected by directing into said bosons a beam of charged particles.

39. A method as claimed in claim 38 wherein said charged particles comprise protons.

40. A method as claimed in claim 38 wherein said charged particles comprise electrons.

41. A method as claimed in any one of claims 32 to 40 wherein bosons of a plurality of different charges are introduced into said evacuated region.

42. A method as claimed in claim 41 wherein said scattering is effected in respect of the bosons of at least one of said charges to produce the coherent boson beam of those bosons.

43. A method as claimed in claim 42 wherein said bosons of two opposite charges are moved in paths which are at least over respective common portions thereof substantially coincident.

44. A method as claimed in claim 43 wherein said bosons of two opposite charges are moved on closed substantially coincident paths, but in opposite directions.

45. A method as claimed in claim 42 wherein said paths are closed and the common portions thereof comprise less than the whole of each respective path, whereby to form over the common portions a common stream of bosons of said two opposite charges, which stream is directed to form said boson beam.

46. As claimed in claim 45 wherein said paths are in the form of elongate loops each defining opposed first and second elongate parallel path portions which are, for each loop, interconnected at opposite ends by end portions of the loop.

47. A method as claimed in claim 46 wherein said loops are side by side so that the common portions of these comprise respective ones of the two elongate path portions of each loop.

48. A method as claimed in claim 47 wherein the bosons are moved in circulatory fashion around each adjacent loop in oppositely directed rotational senses whereby, at the common portions of the paths, the bosons moving

on each path move side by side or in intermingled fashion in the same direction.

49. A method as claimed in claim 47 or claim 48 wherein said bosons of two opposite charges are injected into the paths of movement of each adjacent the entry point to said common portions thereof.

50. A method as claimed in claim 49 wherein scattering is effected by injecting photons in a coherent beam, or other particles, into the bosons moving in each path, at a respective location around each said path.

51. A method as claimed in claim 43 wherein the bosons are moved in at least four streams on respective closed paths arranged in an array which extends in two directions in a plane transverse to the direction of said boson beam.

52. A method as claimed in claim 51 wherein adjacent ones of the closed paths within the array have bosons with respective opposite polarities moved therearound.

53. A method as claimed in claim 52 wherein each said path has two common portions, one substantially coincident with each of two side by side said paths in the array, said common portions extending in a lengthwise direction and bosons of said two different charges being advanced in the same direction along each said common path portion.

54. A method as claimed in claim 53 wherein the common path portions are arranged in a rectangular array when viewed in transverse section.

55. A method as claimed in claim 54 wherein at two tranversely opposed ones of said common path portions within said array bosons of one charge polarity and bosons of the opposite charge polarity are injected, at locations adjacent one ends of the paths, whereby bosons of each of said two charges then form composite streams of substantially neutral electric charge within these two common path portions.

56. A method as claimed in claim 55 wherein at adjacent ends of the paths, opposite said one ends thereof, two beams of charged bosons are extracted.

57. A method as claimed in claim 56 wherein at two other opposed ones of said common path portions, coherent light beams or other scattering inducing particles are injected whereby to render coherent the bosons travelling in those path portions.

58. A method as claimed in any one of claims 32 to 57 wherein said bosons comprise ions.

59. A method as claimed in any one of claims 43 to 57 wherein said bosons of a first of said charges comprise deuterons and the bosons of a second of said charges comprise singly negativly charged deuterium ions.

60. A process for producing energy by fusing two nuclei, characterised in that at least one of said nuclei is provided in a coherent nuclei beam directed at the other of the nuclei.

61. A process as claimed in claim 60 wherein said nuclei are deuterium nuclei.

62. A process as claimed in claim 61, wherein said nuclei beam is one of a plurality of deuteron beams directed at the said other nucleus.

63. A process as claimed in claim 61 or claim 62 wherein said other of said nuclei is the nucleus of one of a number of deuterium atoms of a pellet of a deuterium compound.

64. A process as claimed in claim 63 wherein said compound is deuterium oxide (D_2O).

65. A process as claimed in claim 64 wherein said compound includes a tritium compound.

66. A process as claimed in any one of claims 60 to 65 wherein the or each said beam is provided by at least one macroscopic baser according to any one of claims 1 to 59.

67. A nuclear fusion reactor effective to produce energy by the process of claim 60 comprising a macroscopic baser effective to produce at least one beam of coherent nuclei and means for positioning further nuclei for incidence thereon of said beam.

68: A nuclear fusion reactor as claimed in claim 67, wherein said baser is one of a plurality of basers generating a plurality of beams of coherent nuclei for direction to said further nuclei.

69. A nuclear fusion reactor as claimed in claim 67 or 68 wherein said means comprises means for supplying pellets of a deuterium compound.

70. A nuclear fusion reactor as claimed in any one of claims 67 to 69 wherein the or each said baser is effective to produce a coherent beam of deuterons for incidence or said further nuclei.

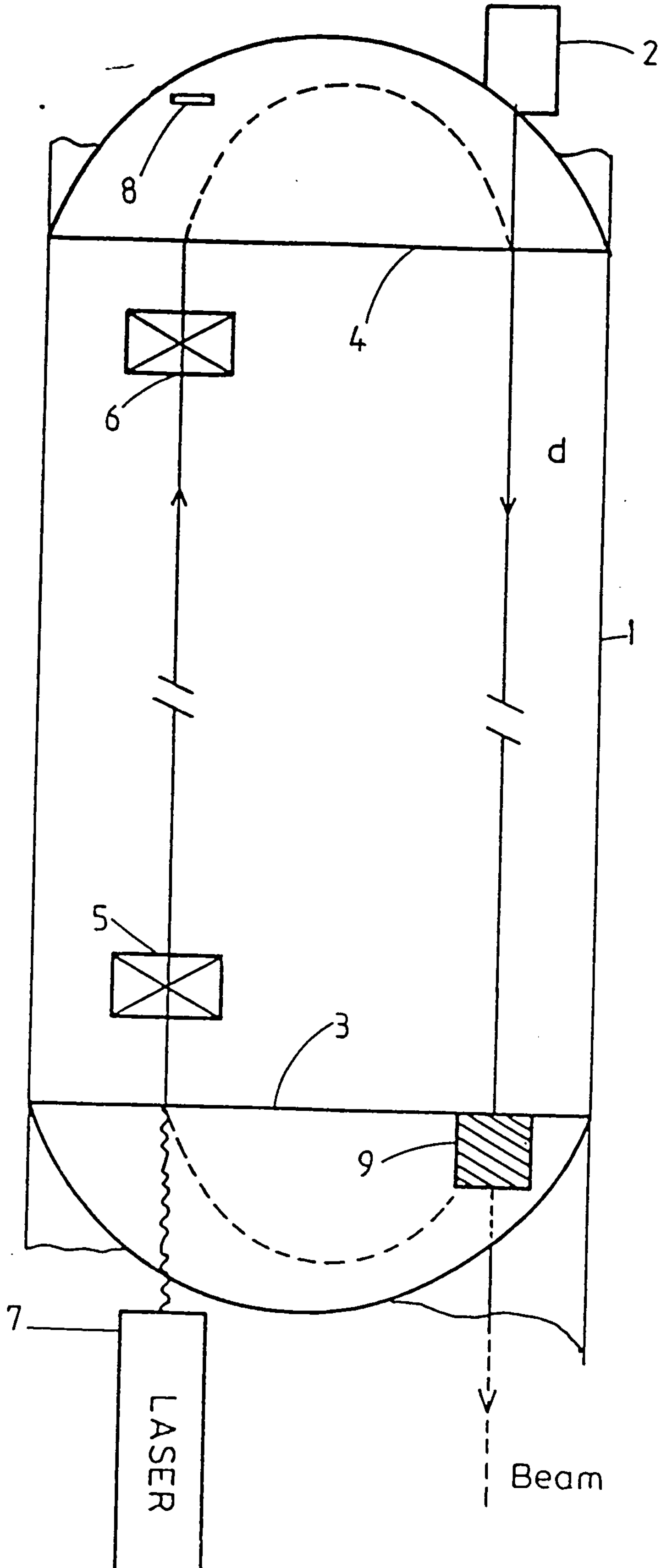


Fig. 1.

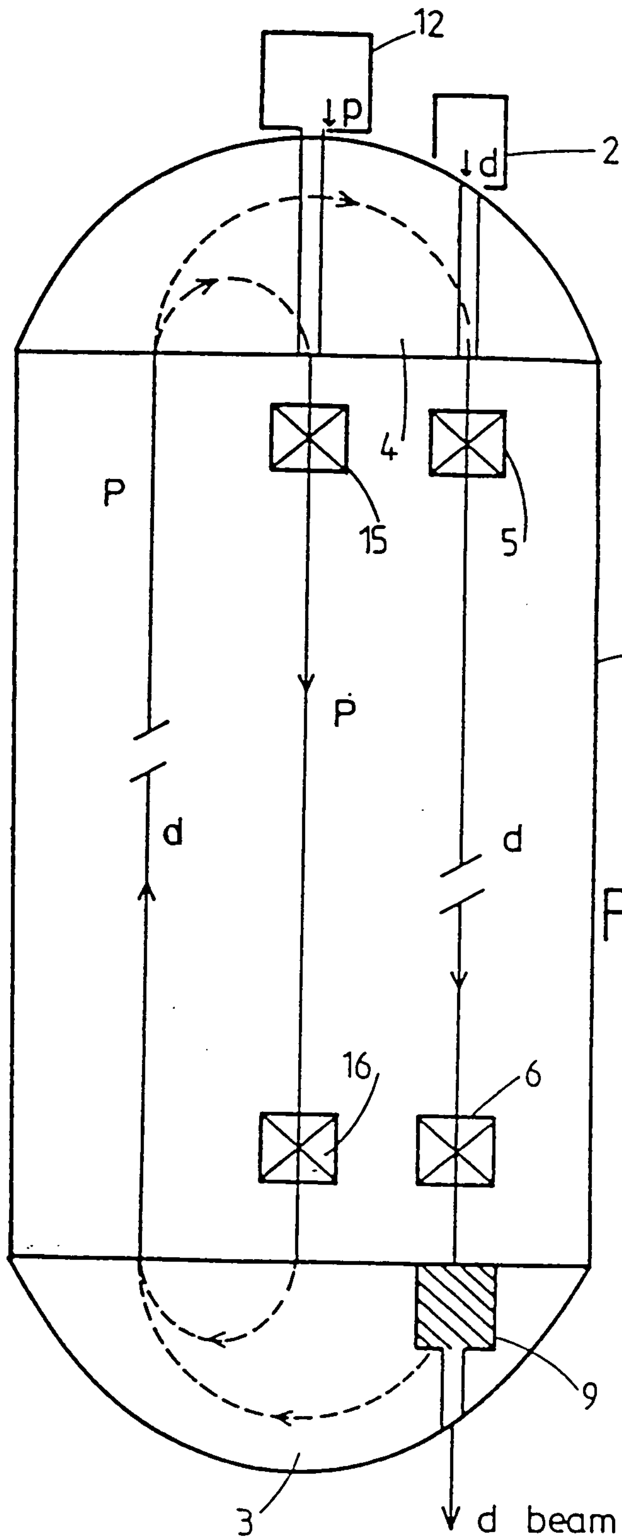


Fig.2.

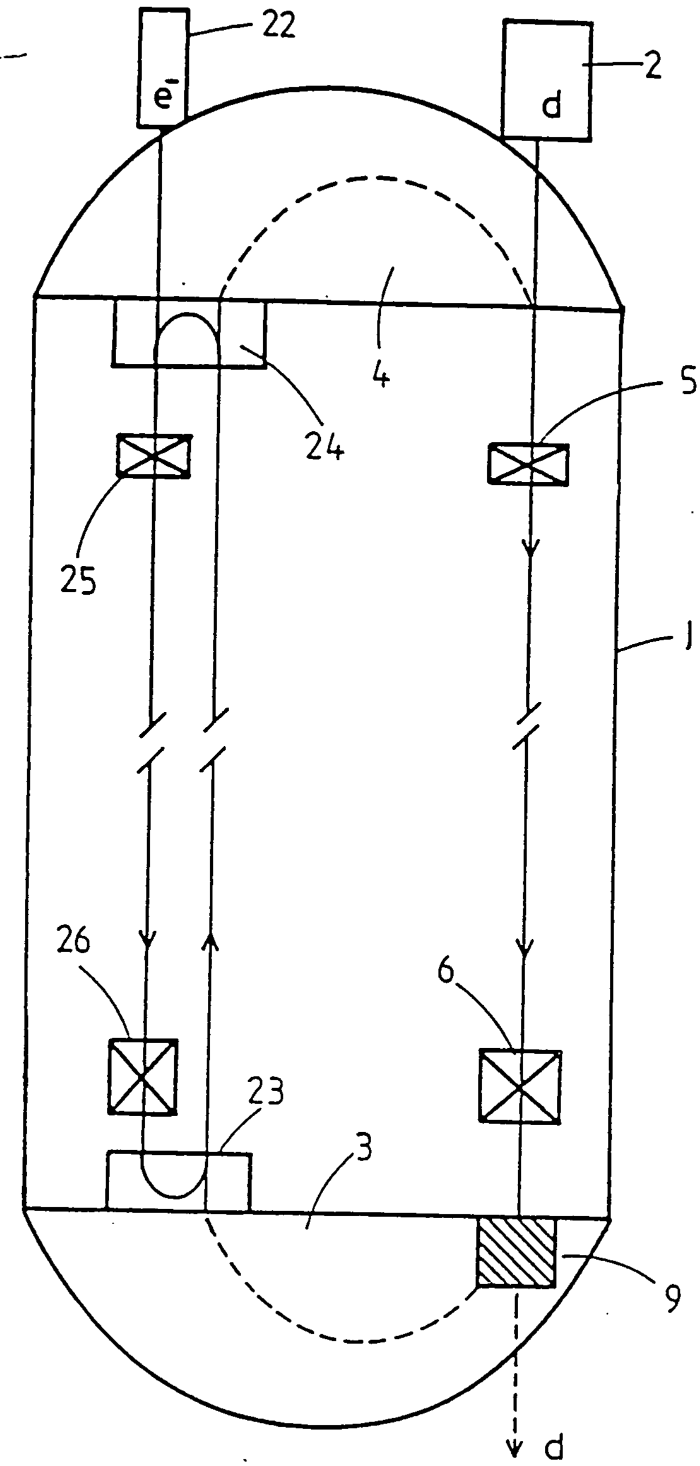


Fig. 3.

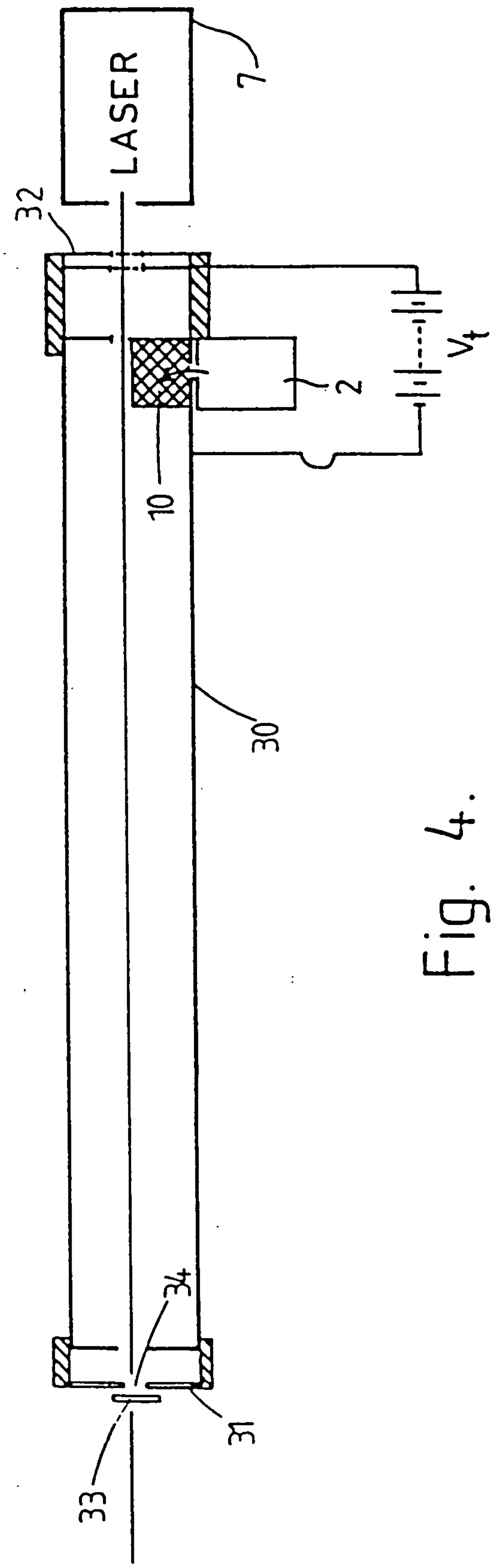
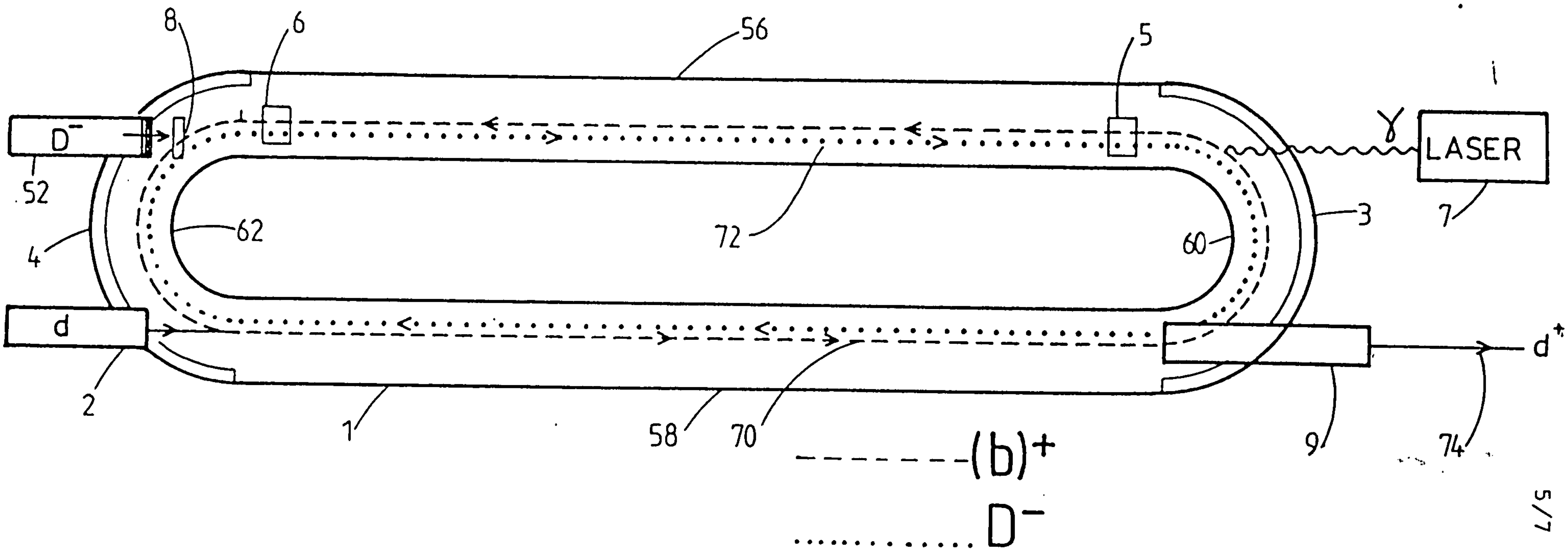


Fig. 4.

Fig. 5.



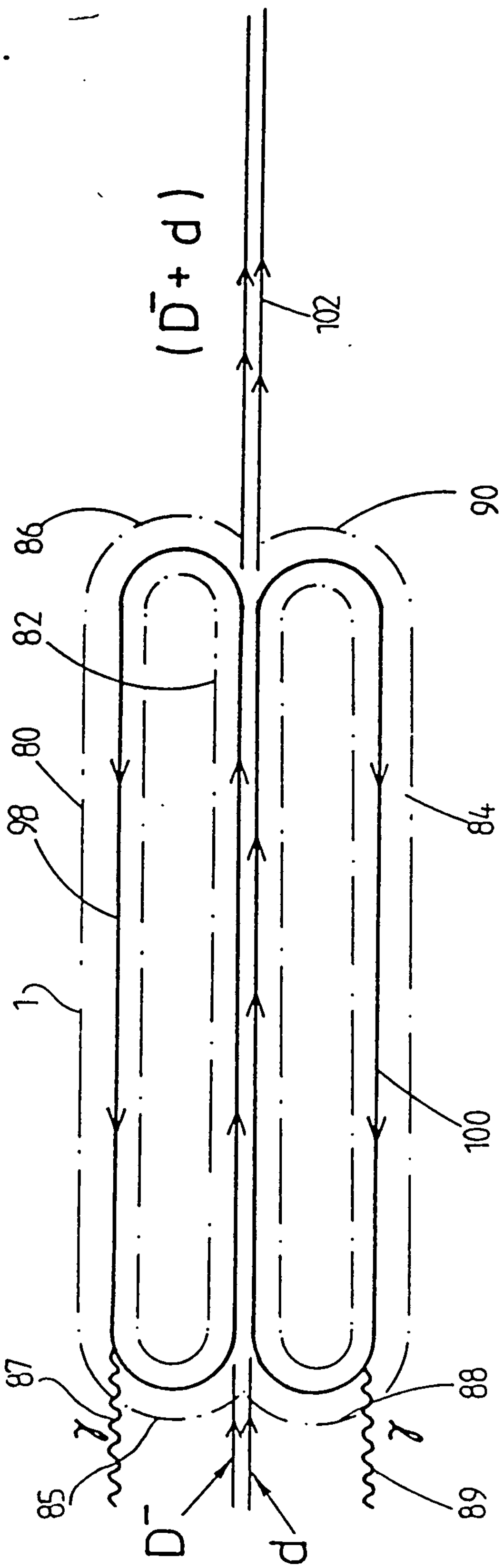
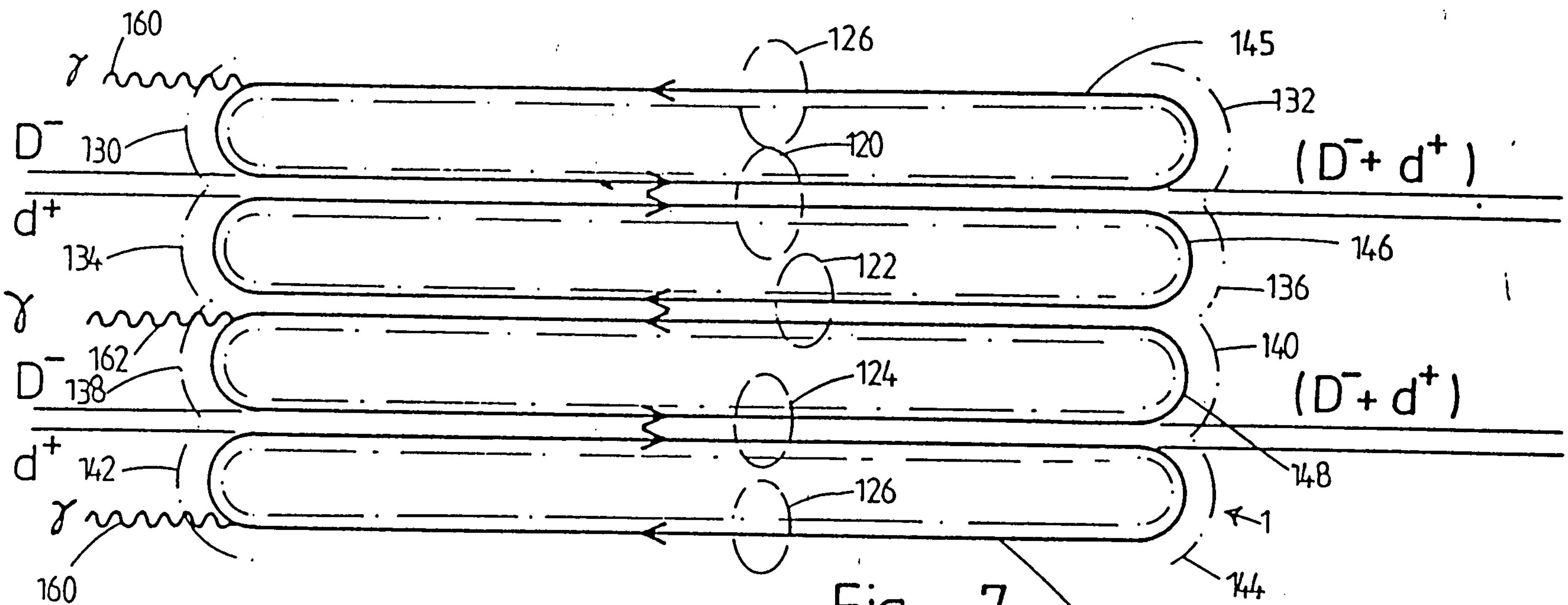
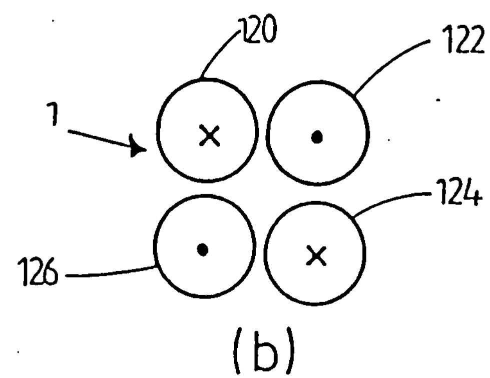


Fig. 6.



160
γ
126
145
132
D⁻
130
120
(D⁻+ d⁺)
d⁺
134
146
122
136
γ
162
140
D⁻
138
124
(D⁻+ d⁺)
148
d⁺
142
126
γ
1
160
144
150

Fig. 7.



120
122
1
124
126
(b)

Fig. 8.